Functionality check of the EMC simulation in PandaRoot

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PANDA Collaboration Meeting 18/3

GSI, Darmstadt, Germany

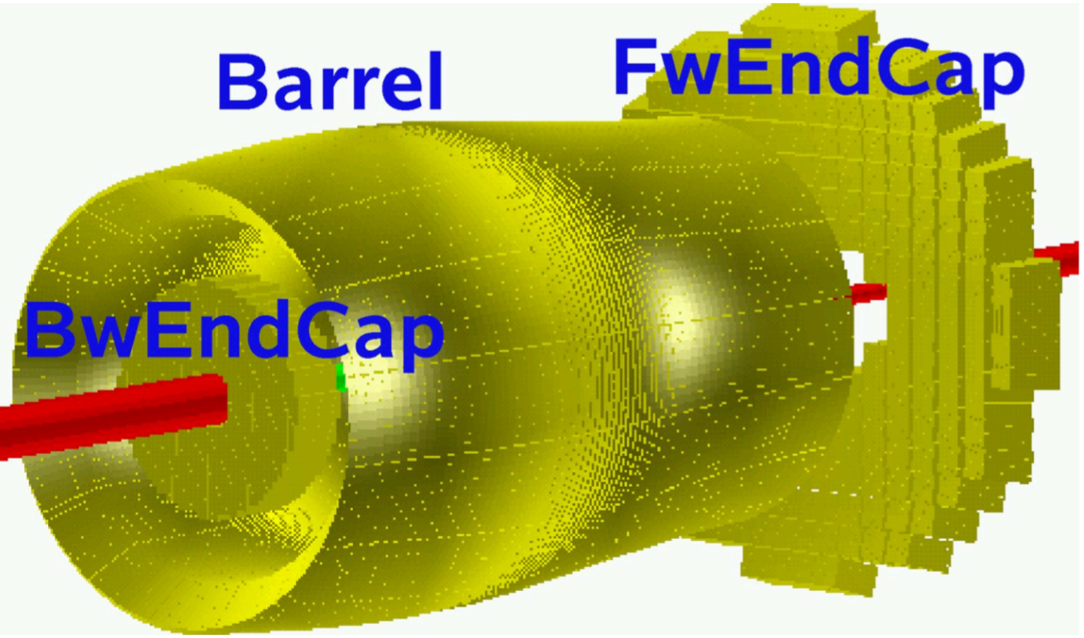
Outline

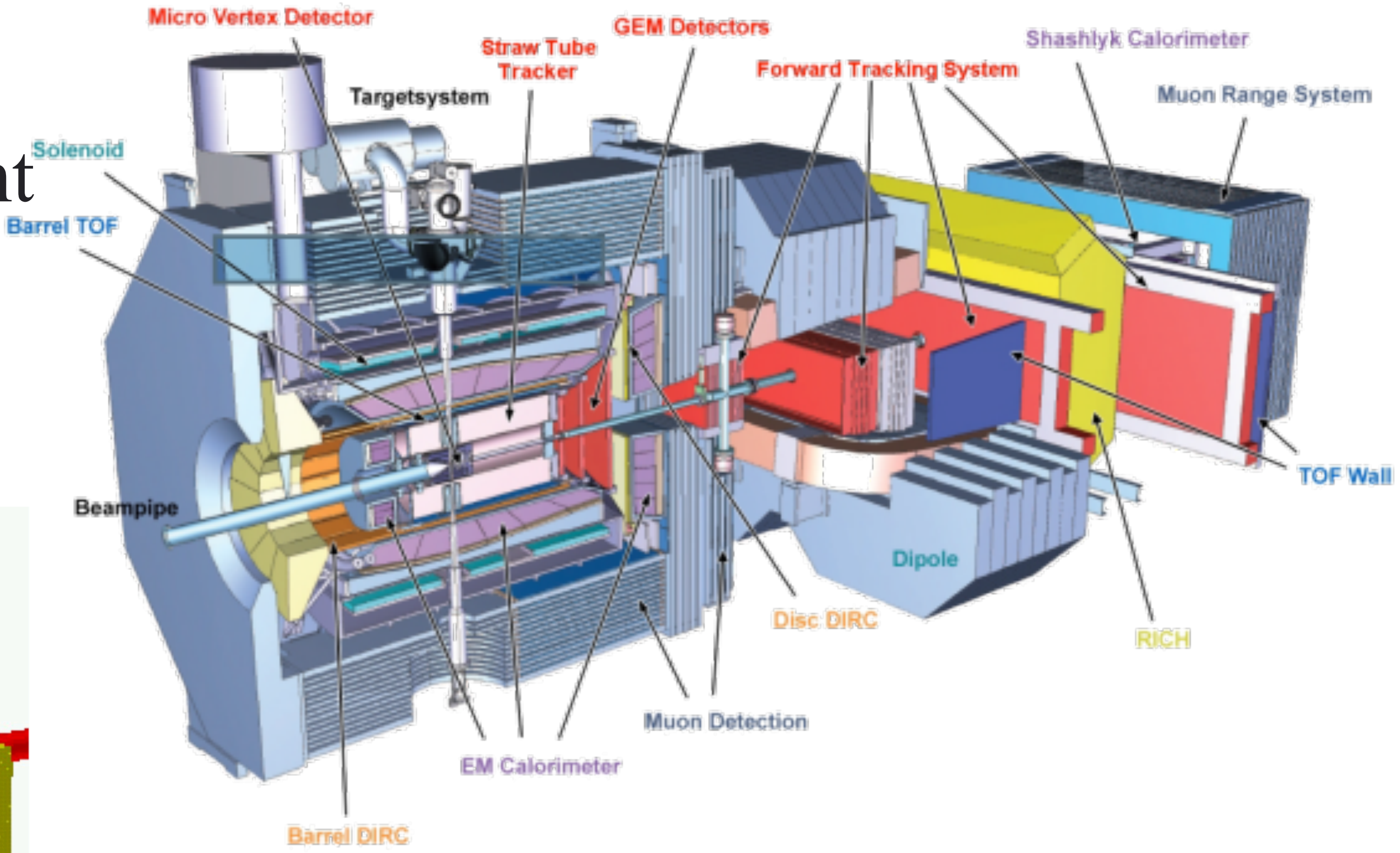
- Introduction
  - ➢ Detector
  - ➢ Target EMC calorimeter
- Simulation
  - ➢ Detector response
  - ➢ Electronic response
- Summary

Refer to talk by Yankun Sun in Computing session.

Introduction: Detector

- Target EMC
  - ➢ energy measurement
  - ➢ position
  - ➢ PID





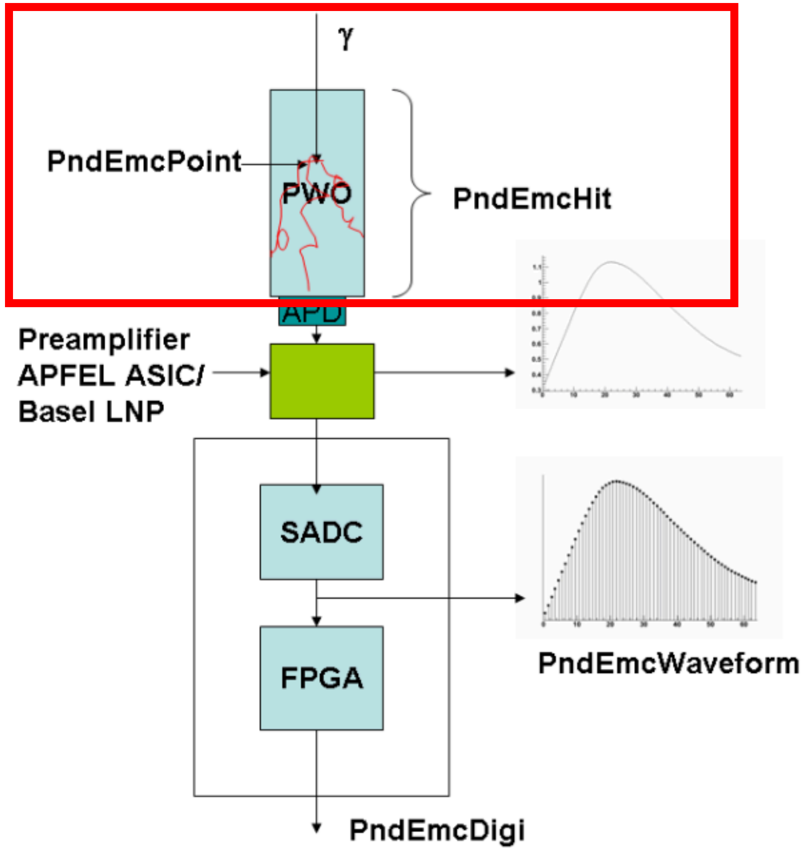
FairRoot version: v-17.10b

PandaRoot version: dev

EMC Simulation

Goal: functionality check

- What kind of data processed?
- Are the results reasonable?



D. Melnychuk 24.07.2012

Simulation setup:

- Geometry: beam pipe, barrel EMC
- Simulation Engine: Geant4
- Generator: Box
- Setting:
  - particle: 22 (gamma)
  - position: (0, 0, 0)
  - direction: point to a barrel crystal
  - Momentum: from 1 to 15 GeV/c, 1 GeV/c per step

EMC Simulation: detector response

Process:

- shower
- light collection

Shower at truth level: information in PndMCTrack

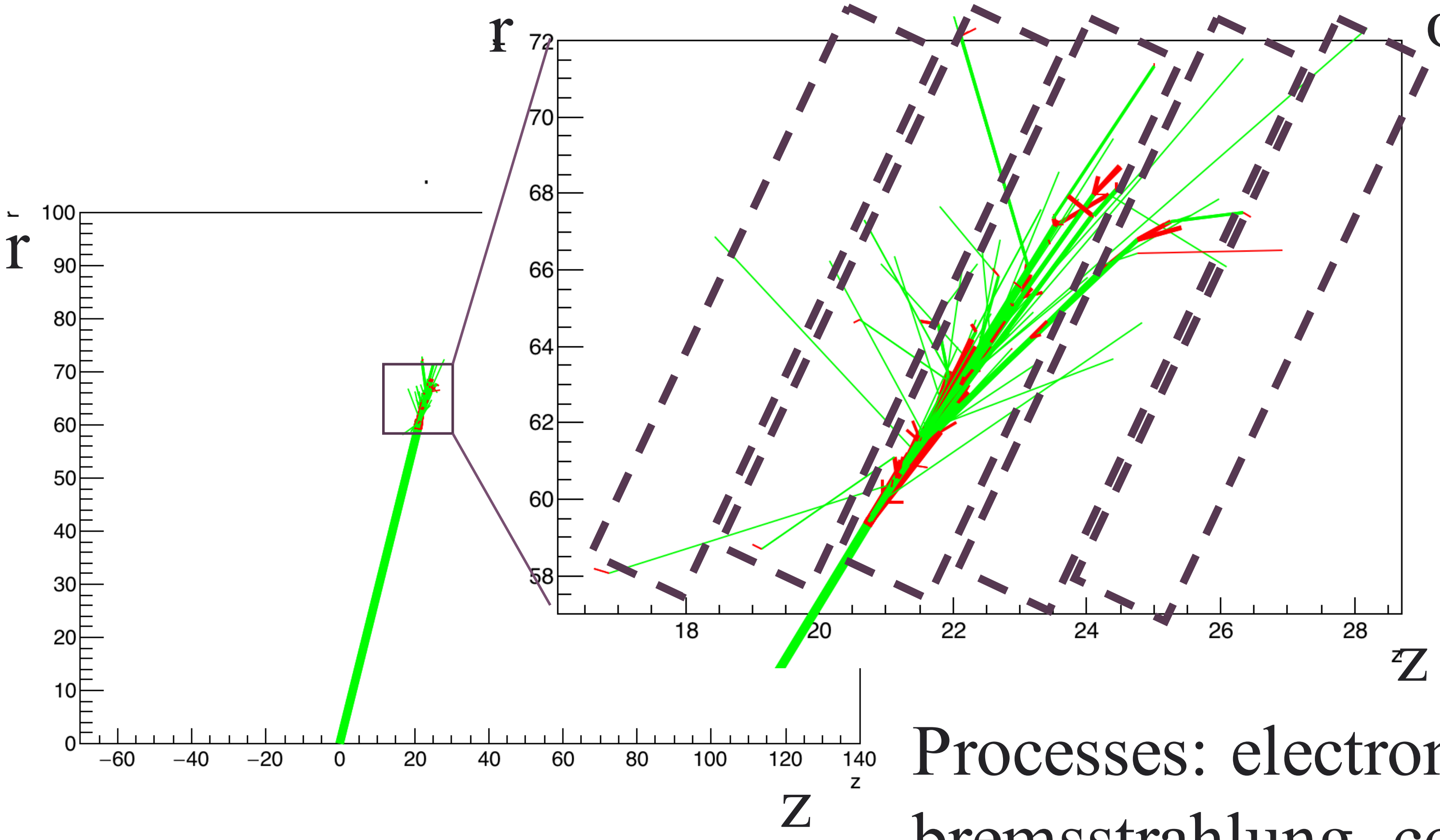
PndMCTrack: public TObject // information from G4/G3

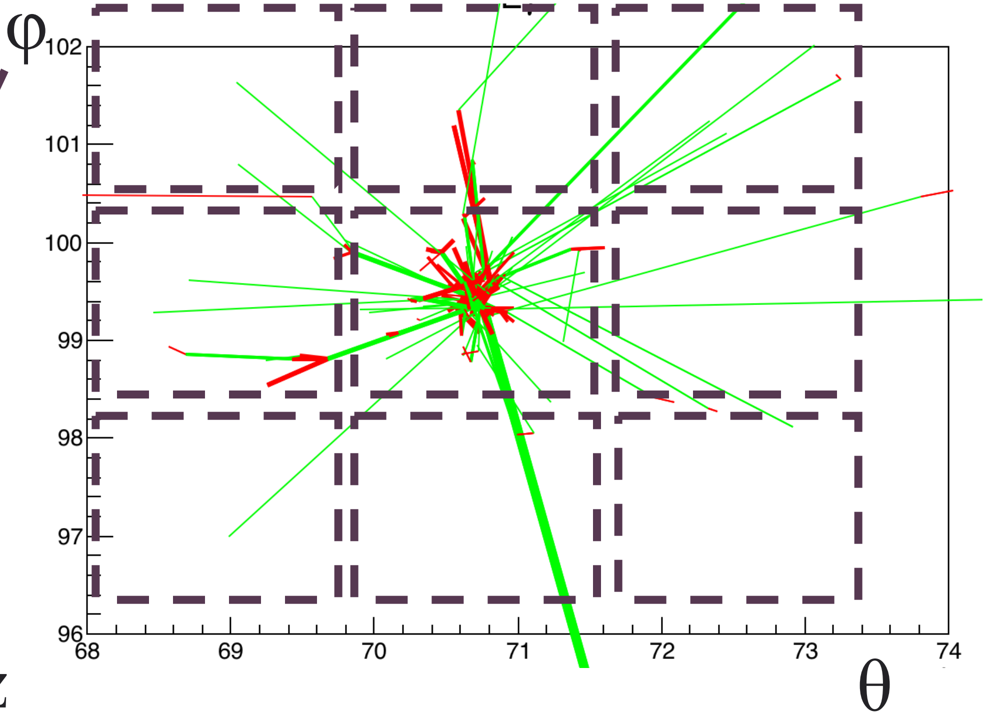
```
/**  PDG particle code  **/
Int_t  fPdgCode;
/** Momentum components at production [GeV]  **/
Double32_t fPx, fPy, fPz, fE;
/**  Index of mother track. Zero( Minus One???) for primary particles.  **/
Int_t  fMotherID;
Int_t  fSecondMotherID;
/** Flag if particle was created (bit 0) and/or decayed (bit 1) by generator **/
Int_t fGeneratorFlags;
/** Coordinates of start vertex [cm, ns]  **/
Double32_t fStartX, fStartY, fStartZ, fStartT;
Int_t  fPoints;
```

EMC Simulation: detector response

- Shower at truth level:

  massive tracks from one input particle





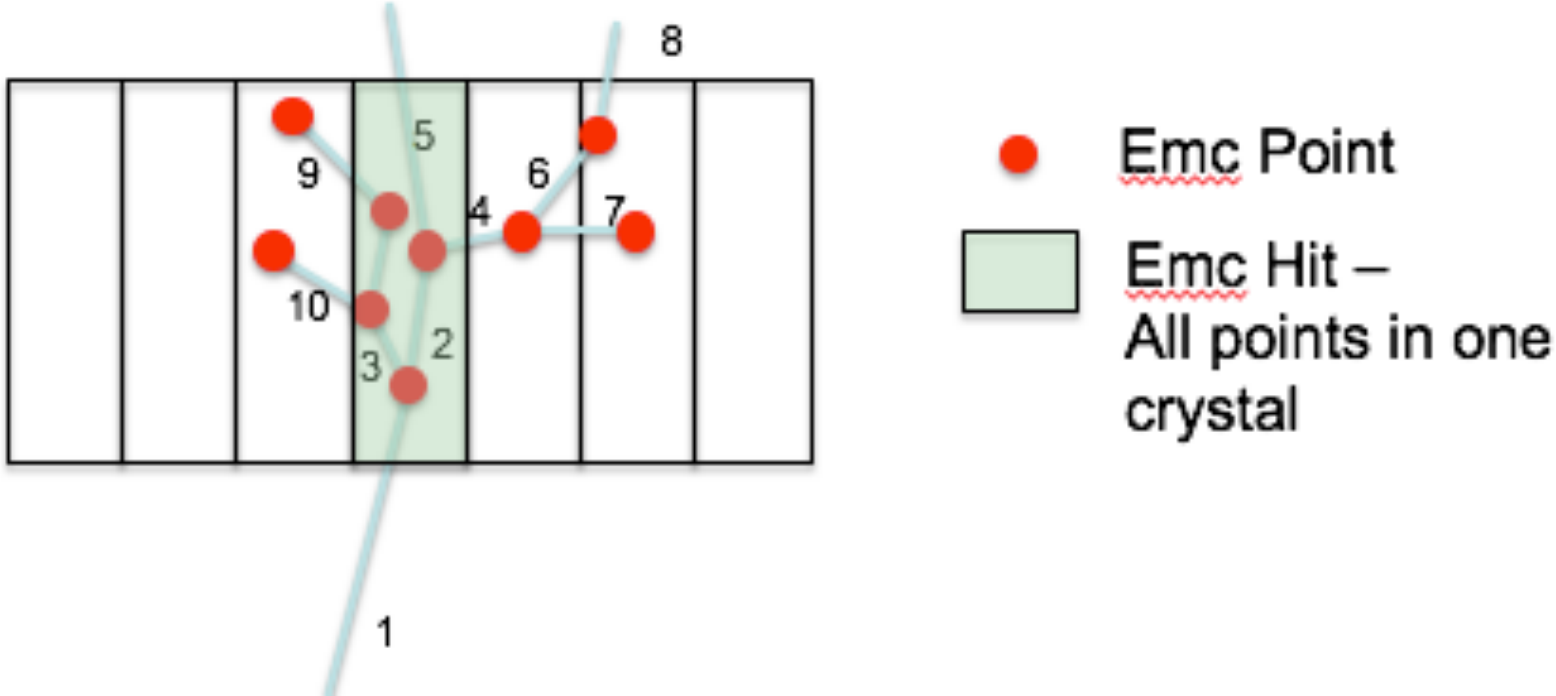
Processes: electron pair effect, bremsstrahlung, compton scattering, …

EMC Simulation: detector response

- Shower:

  one track generates a few points

  a few points contribute to one hit

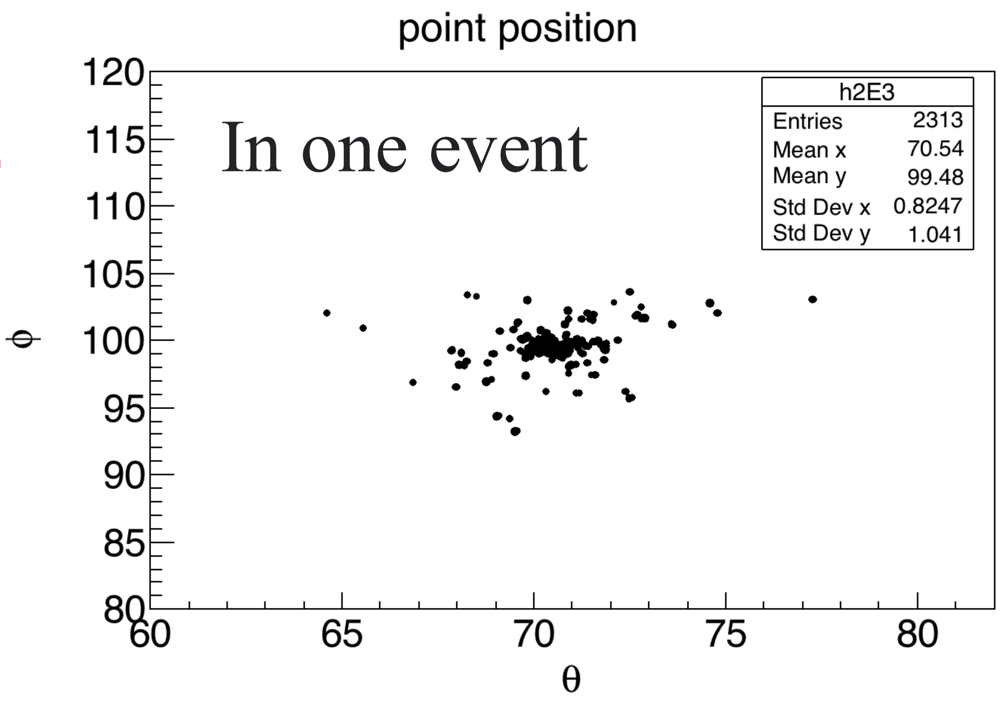


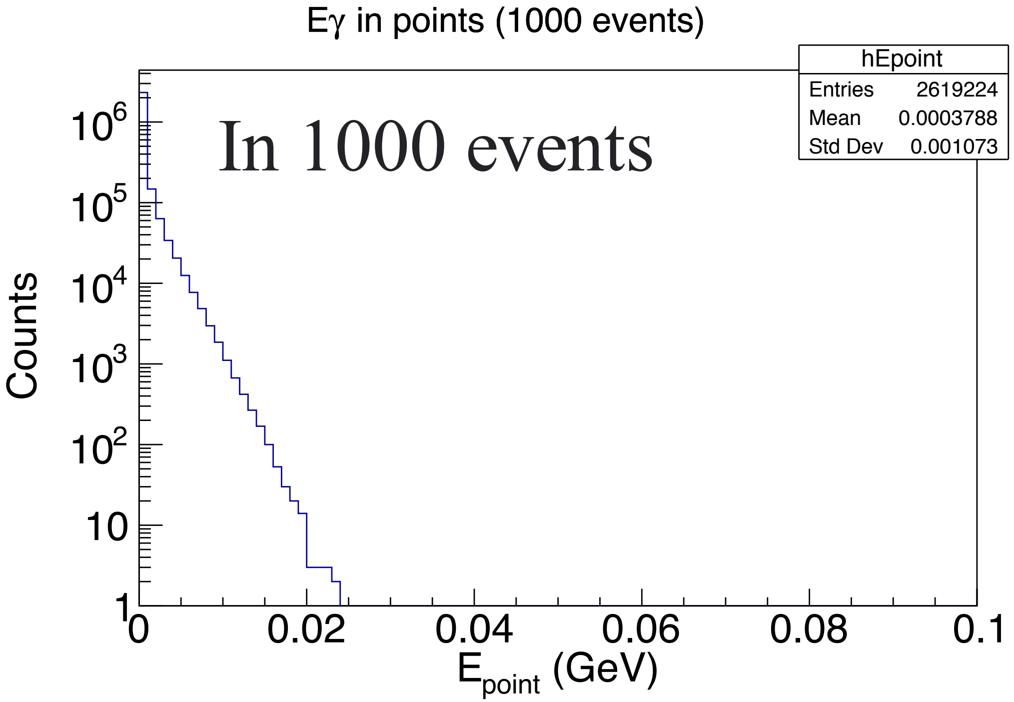
EMC Simulation: detector response

- Shower:

  one track generates a few points

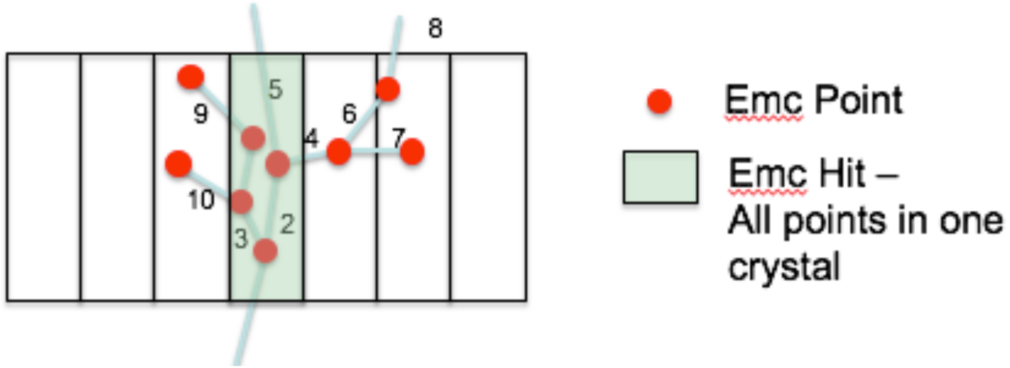
```
PndEmcPoint : public FairMCPoint
    Short_t nModule;        // Module number
    Short_t nRow;           // Row number
    Short_t nCrystal;       // Crystal number
    Short_t nCopy;          // Copy number
    Bool_t fEntering;       //< Is particle entering into crystal
    Bool_t fExiting;        //< Is particle exiting the crystal

FairMCPoint
    Int_t fTrackID;                 ///< Track index
    UInt_t fEventId;                ///< MC Event id
    Double32_t fPx, fPy, fPz;       ///< Momentum components [GeV]
    Double32_t fTime;               ///< Time since event start [ns]
    Double32_t fLength;             ///< Track length since creation [cm]
    Double32_t fELoss;              ///< Energy loss at this point [GeV]
    Int_t      fDetectorID;         ///< Detector unique identifier
    Double32_t fX, fY, fZ;          ///< Position of hit [cm]
```





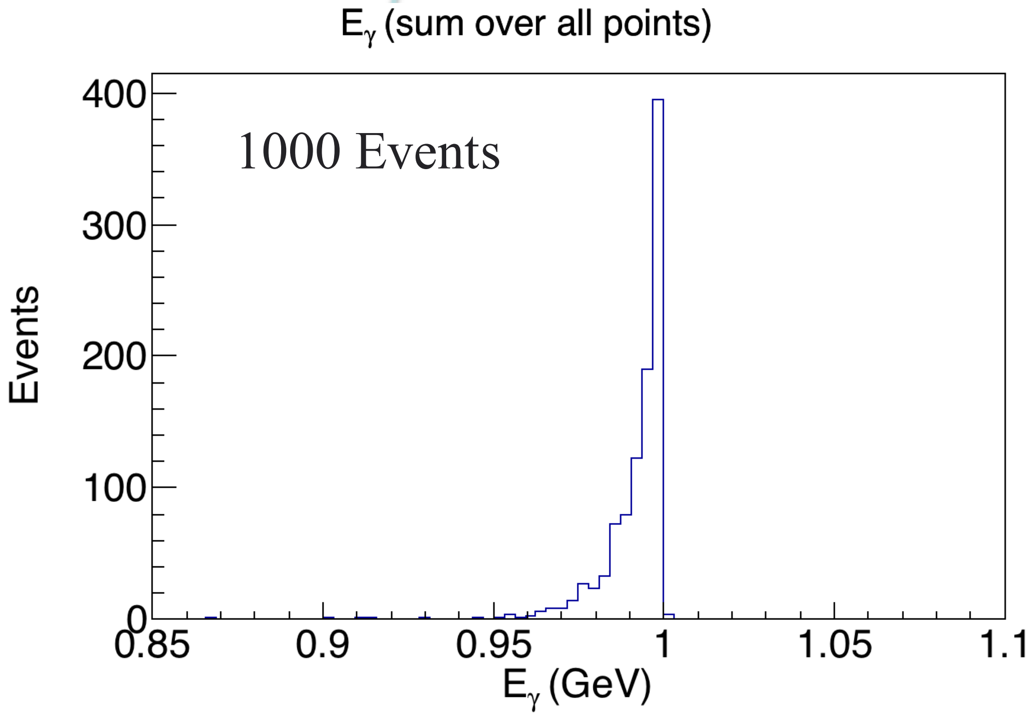
EMC Simulation: detector response

- Shower:
  one track generates a few points



Total Energy in PndEmcPoint

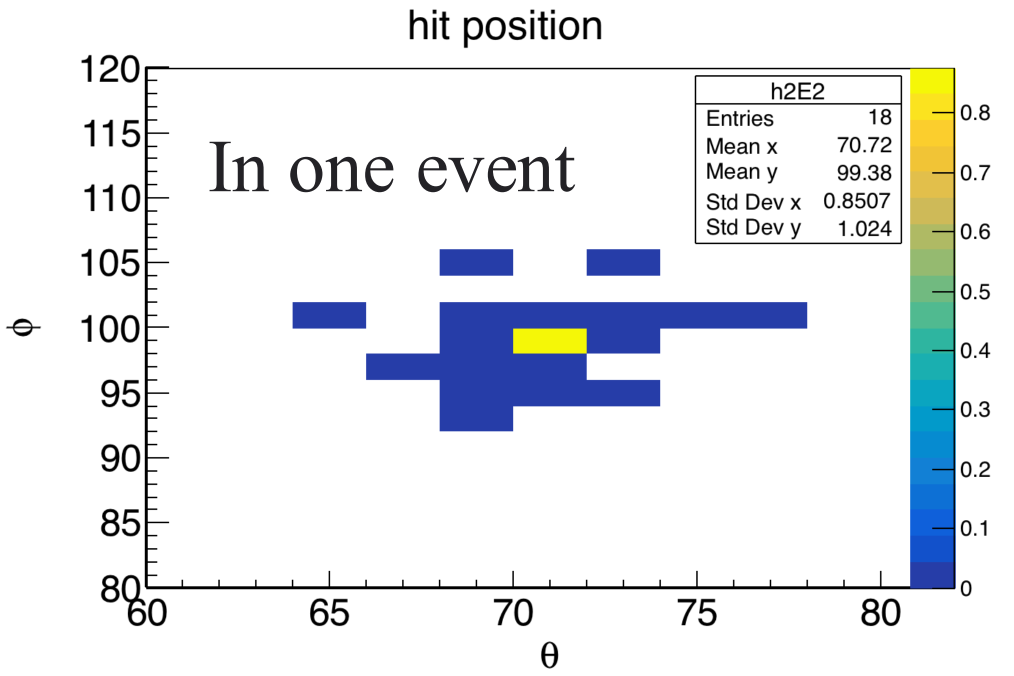
- Energy leakage
  - trace via FairLink

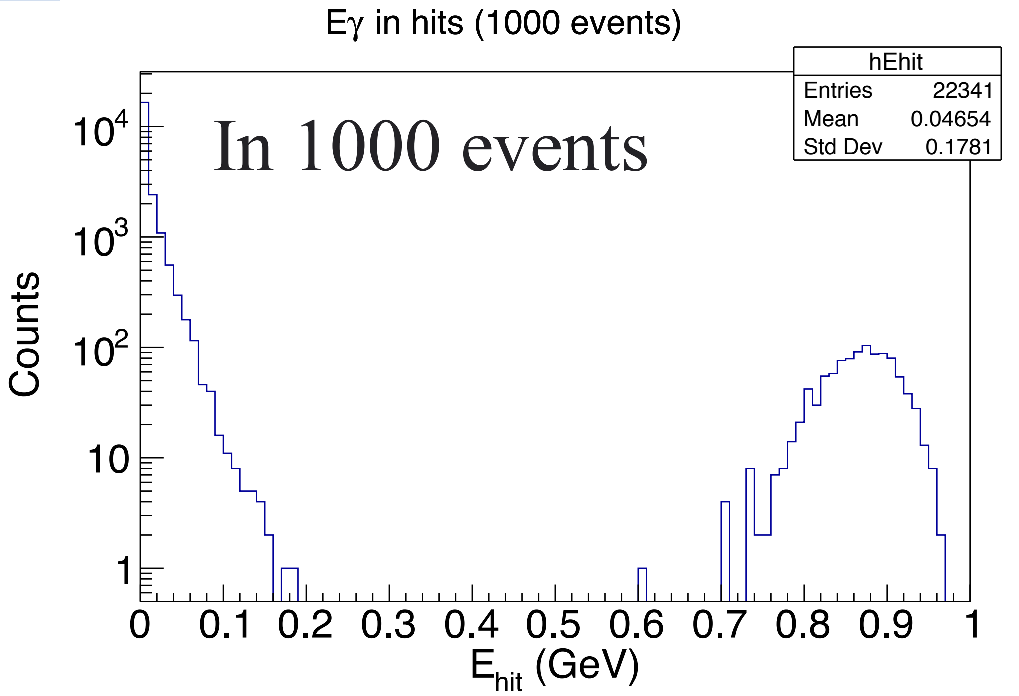


EMC Simulation: detector response

- Light collection:
  a few points contribute to one hit

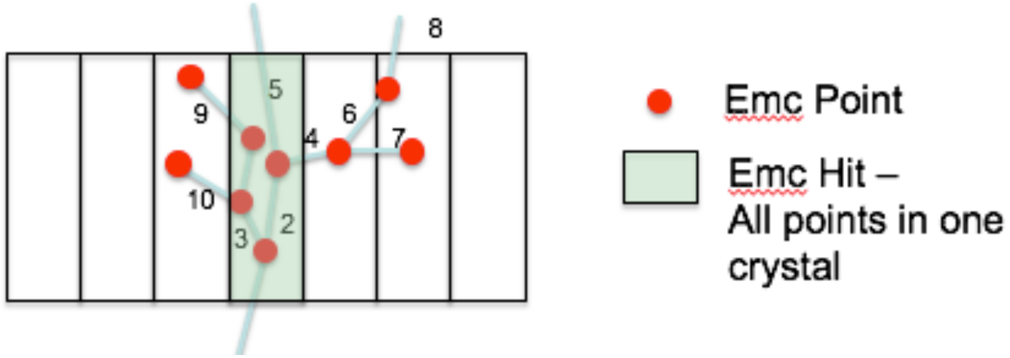
```
PndEmcHit : public FairHit
    Double32_t fTime;      // time
    Double32_t fEnergy;    // hit amplitude
    std::vector<Int_t> fMcList; //  Mc TrackIndex contributed to hit
    std::vector<PndEmcPoint*> fPointList; //  points contributed to hit
    FairMultiLinkedData fTrackEntering; // Links to tracks entering the cryst
    FairMultiLinkedData fTrackExiting;  // Links to tracks exiting the crystal

FairHit
    Double32_t fDx, fDy, fDz;   ///< Errors of position [cm]
    Int_t      fRefIndex;       ///< Index of FairMCPoint for this hit
    Int_t      fDetectorID;     ///< Detector unique identifier
    Double32_t fX, fY, fZ;      ///< Position of hit [cm]
```





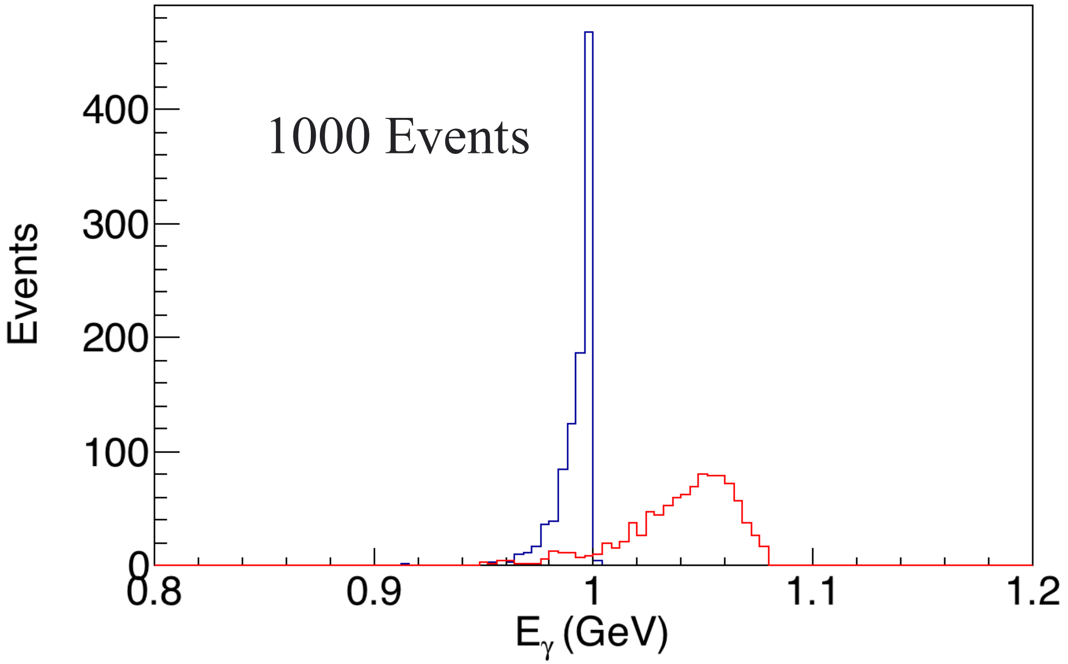
EMC Simulation: detector response

➤ Light collection:
a few points contribute to one hit



Total Energy in PndEmcPoint
Total Energy in PndEmcHit

- Difference in hits and points



EMC Simulation: detector response

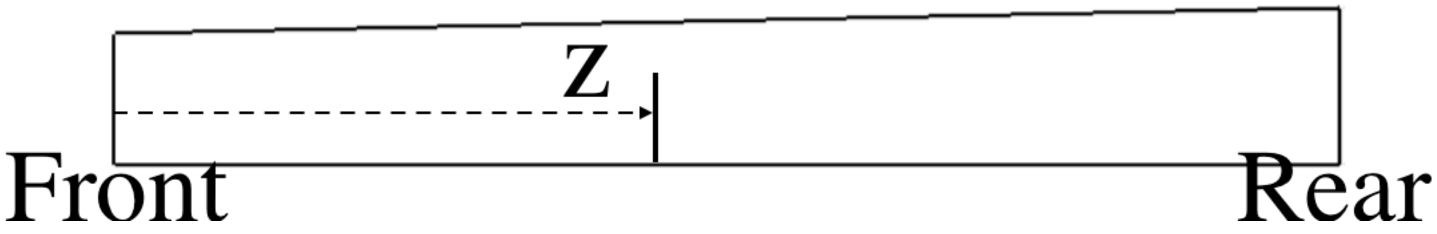
- Light collection:
  a few points contribute to one hit

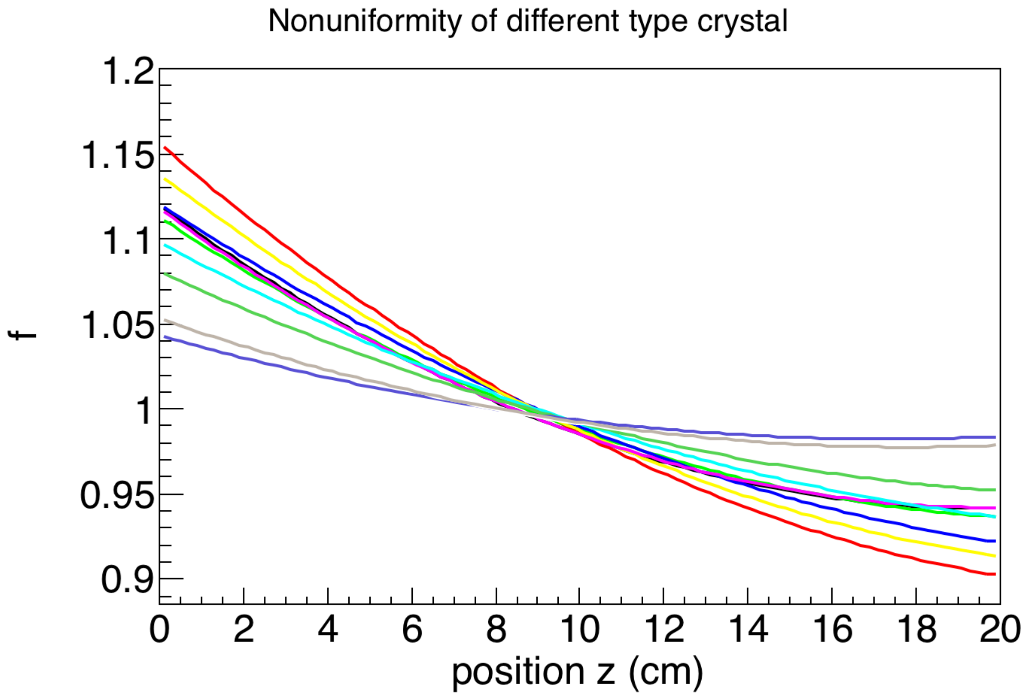
Difference between EmcHit and EmcPoint

HitProducer: nonuniform light yield

$$E_{\text{hit}} = \sum f \cdot E_{\text{point}}$$

$$f = c_0 + z(c_1 + z \cdot c_2)$$





EMC Simulation: detector response

- Light collection:
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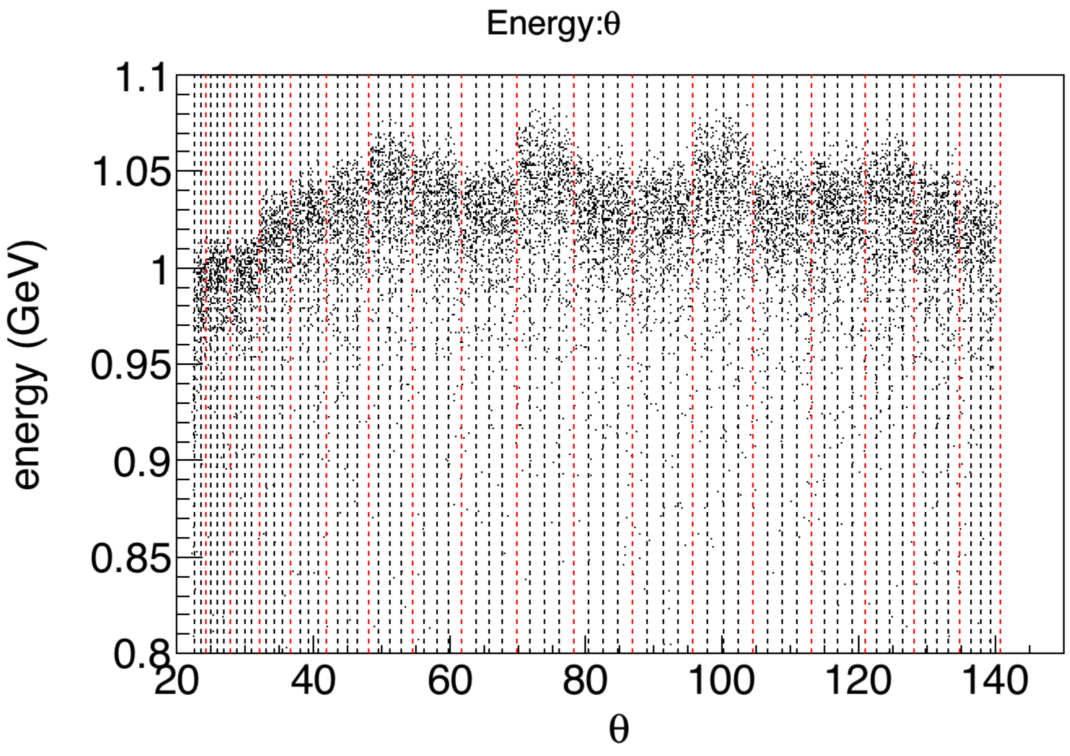
Difference between EmcHit and EmcPoint

HitProducer: nonuniform light yield

$$E_{\text{hit}} = \sum f \cdot E_{\text{point}}$$

$$f = c_0 + z(c_1 + z \cdot c_2)$$

Fluctuation in θ direction

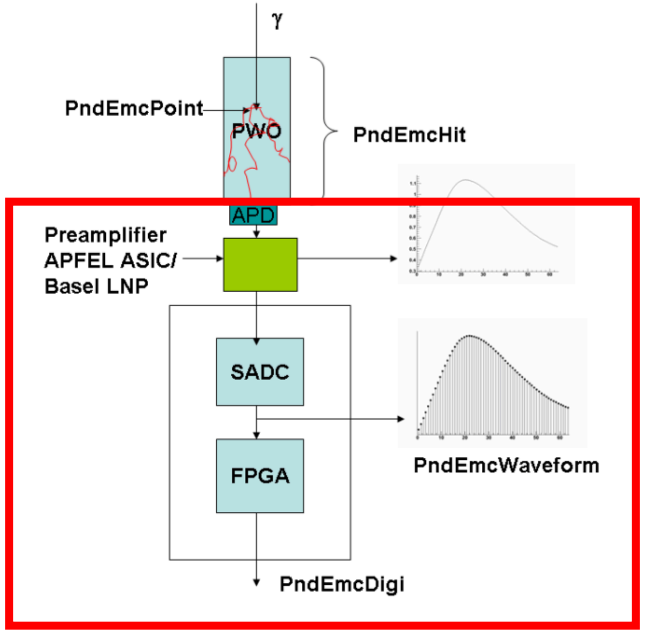


EMC Simulation: electronic response

Process

- Hit to Waveform
  - APD response: photon statistics, quantum efficiency, …
  - ADC: pulse shape, sampling, …
  - Electronic noise: white noise, one bit resolution, …

- Digitization
  - Threshold
  - Filter
  - Peak finding
  - …

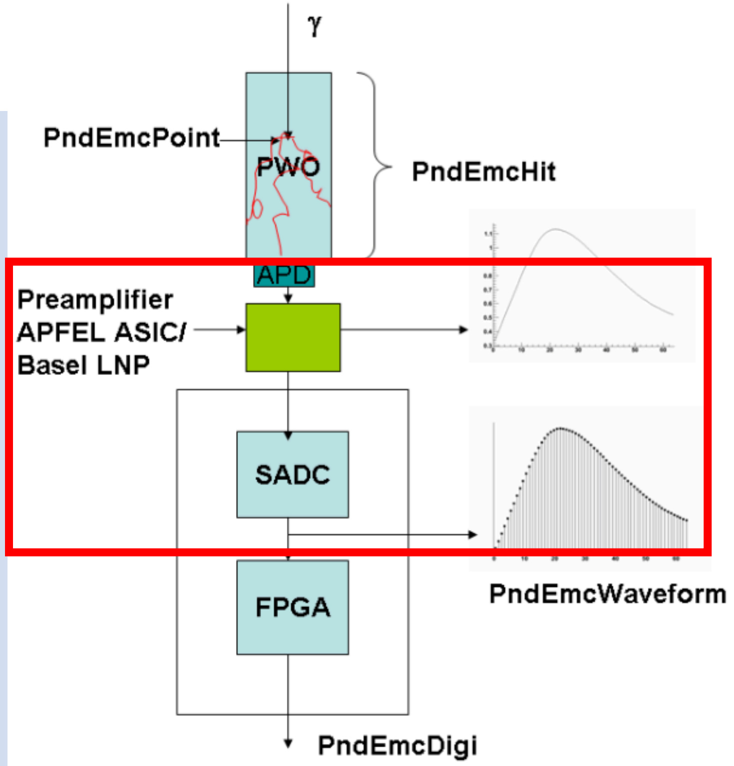


EMC Simulation: electronic response

- Hit to Waveform: PndEmcWaveform

```
PndEmcWaveform: public FairTimeStamp

    Int_t fTrackId;
    Int_t fDetectorId;
    Int_t fWaveformLength;
    std::vector<Double_t>  fSignal; // Signal after FADC
    std::vector<Double_t>  fSignalError; // Signal after FADC
    Int_t fHitIndex;
    Double_t fSampleRate;   //in s^(-1)
    Double_t fBaselineValue;
    std::vector<Int_t>     fEvt;//combined waveforms from which events, for check.
    //for pileup
    static Double_t BarrelOverlapTime;
    static Double_t ForwardOverlapTime;
    static Double_t ShashylikOverlapTime;
```



EMC Simulation: electronic response

➢ Hit to Waveform: PndEmcWaveform
generated via task "PndEmcHitsToWaveform"

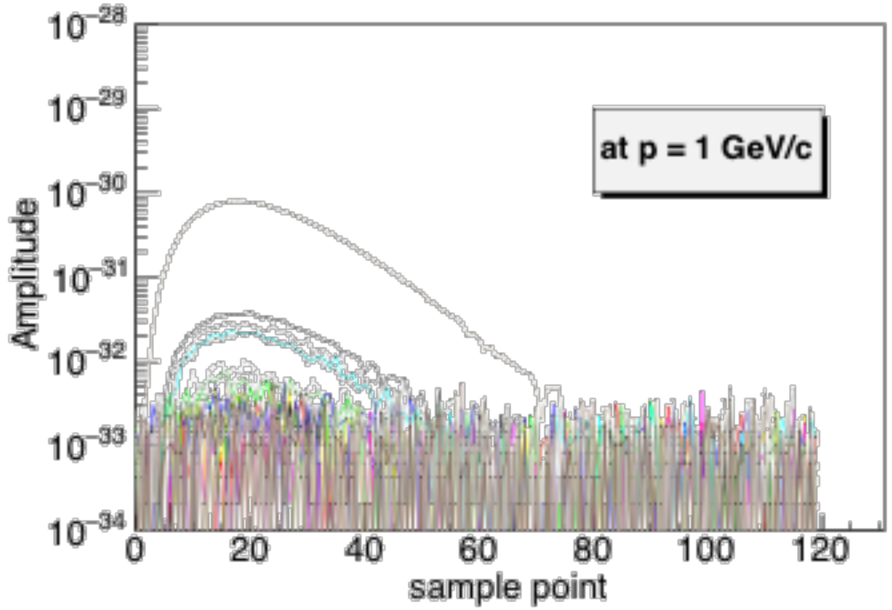
Pulse shape:

$$A\left(\frac{e^{-\Delta t\cdot l_{int}}\cdot\Delta t^3}{6(l_{sig}-l_{int})}-\frac{e^{-\Delta t\cdot l_{int}}\cdot\Delta t^2}{2(l_{sig}-l_{int})^2}+\frac{e^{-\Delta t\cdot l_{int}}\cdot\Delta t}{(l_{sig}-l_{int})^3}-\frac{e^{-\Delta t\cdot l_{int}}}{(l_{sig}-l_{int})^4}+\frac{e^{-\Delta t\cdot l_{sig}}}{(l_{sig}-l_{int})^4}\right)$$

$\Delta t = t - t_0$; $l_{int} = 1/t_{int}$; $l_{sig} = 1/t_{sig}$;
t_{int}: ASIC sampling int time, 70 ns
t_{sig}: crystal sampling time, 12 ns

example in one event

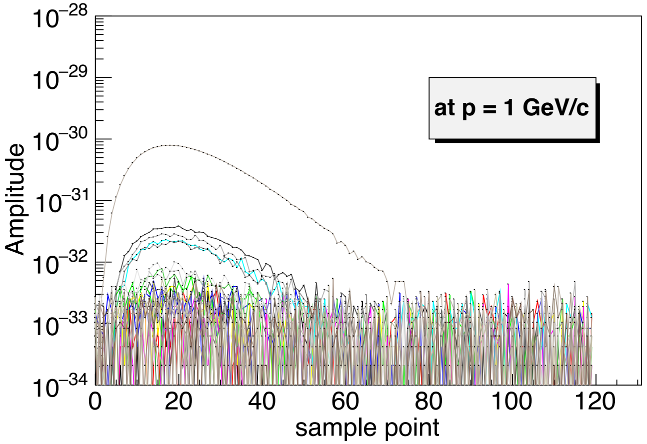
- 28 hits, 28 waves



EMC Simulation: electronic response

- Hit to Waveform: PndEmcWaveform

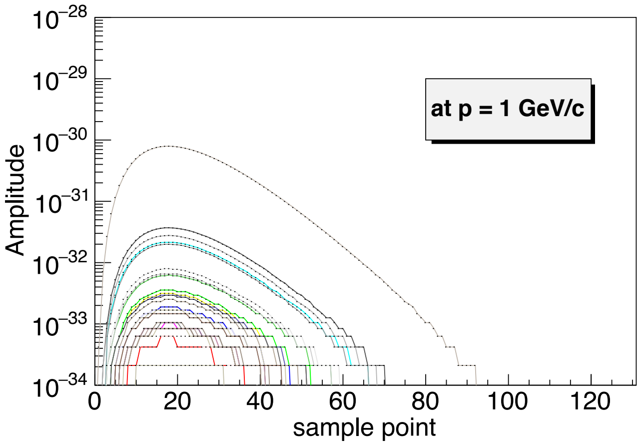
  noise effect



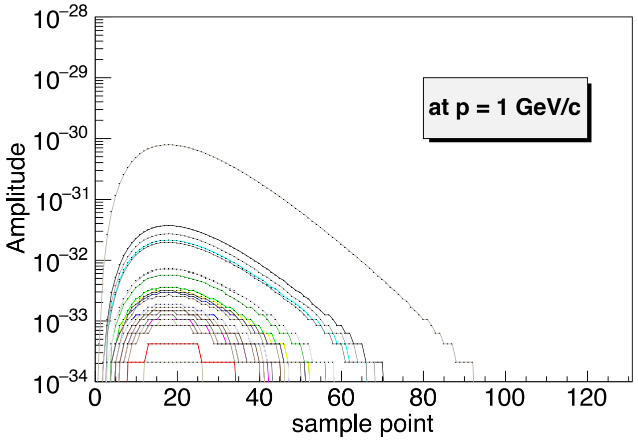
noise

elec noise: 1.5e-3

pho stat: $\frac{1}{\sqrt{E\times 500\times\frac{200}{745}\times 0.7}}$

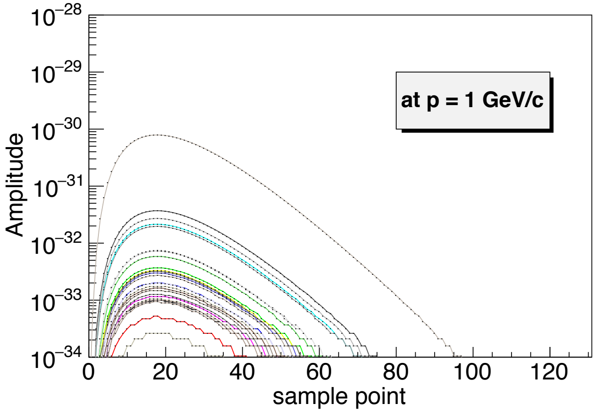


no elec noise



no elec noise

no pho stat



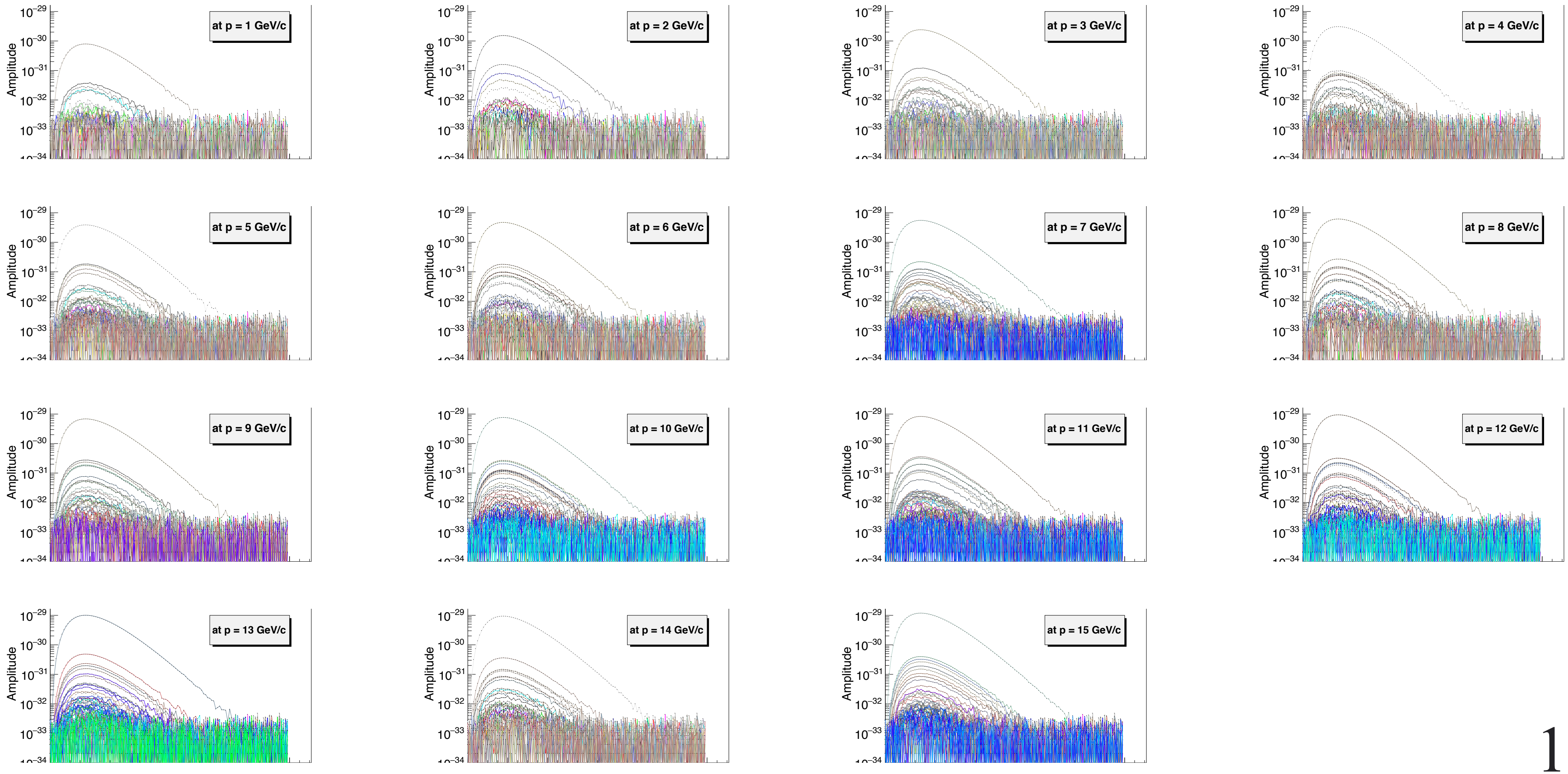
no elec noise

no pho stat,

Nbits=16 →18

EMC Simulation: electronic response

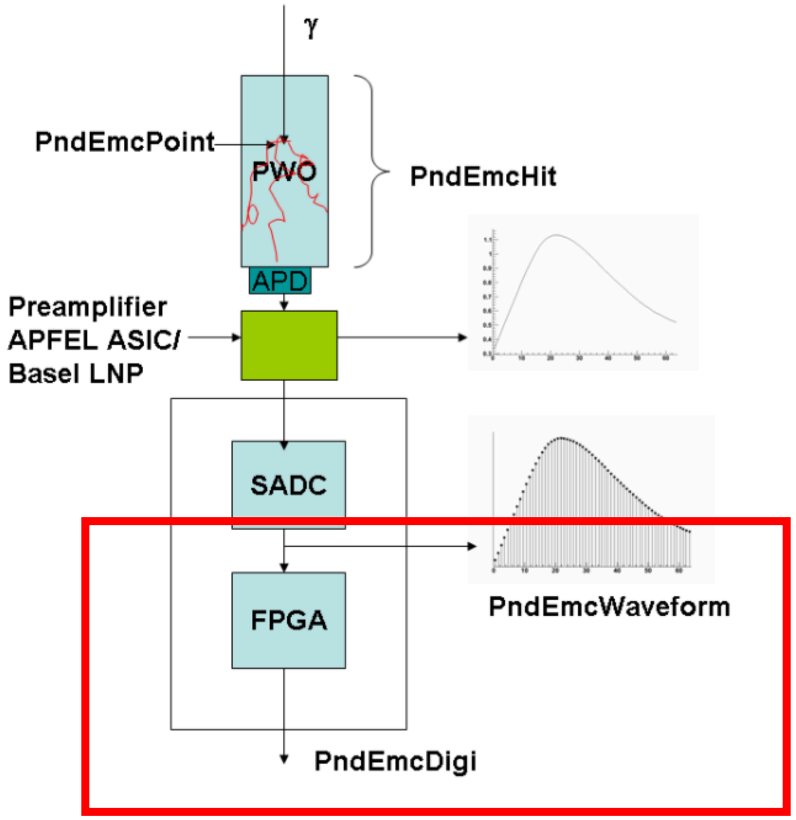
➢ Hit to Waveform: PndEmcWaveform, energy relation



EMC Simulation: electronic response

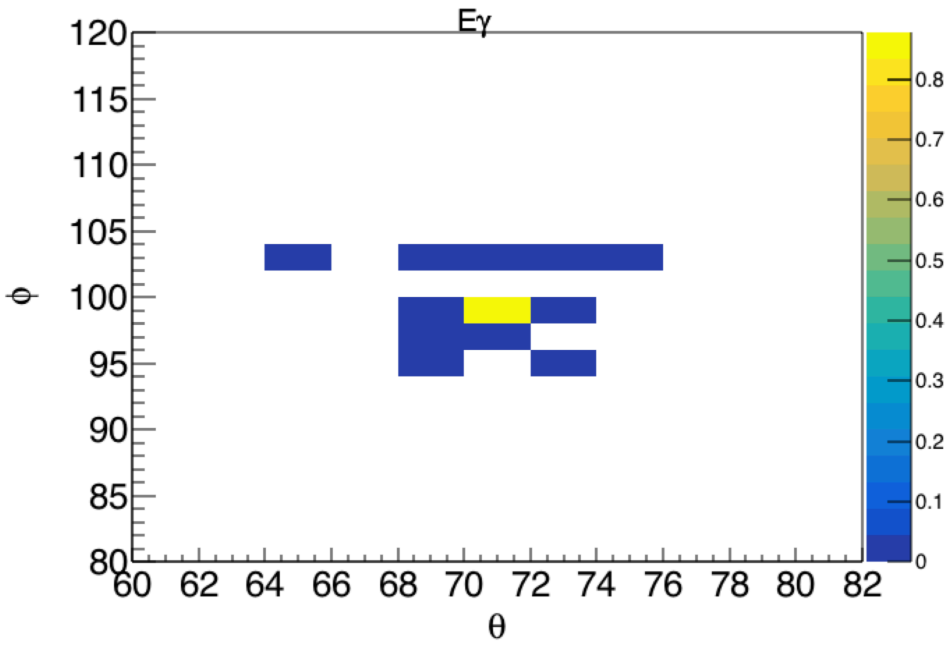
- Digitization: PndEmcDigi
  generated via task “PndEmcWaveformToDigi”

```
PndEmcDigi : public FairTimeStamp
        Int_t fEvtNo;
        Double_t fEnergy;     // digi amplitude
        Int_t fTrackId;
        Int_t fDetectorId;
        Int_t fHitIndex; //  Index of hit which is converted to digi
        TVector3 fWhere;
        Int_t fThetaInd;
        Int_t fPhiInd;
        Double_t fTheta;
        Double_t fPhi;
        static double fRescaleFactor;
        static double fPositionDepthPWO;
        static double fPositionDepthShashlyk;
```



EMC Simulation: electronic response

- Digitization: PndEmcDigi
  - Threshold
  - Filter
  - Peak finding
  - …



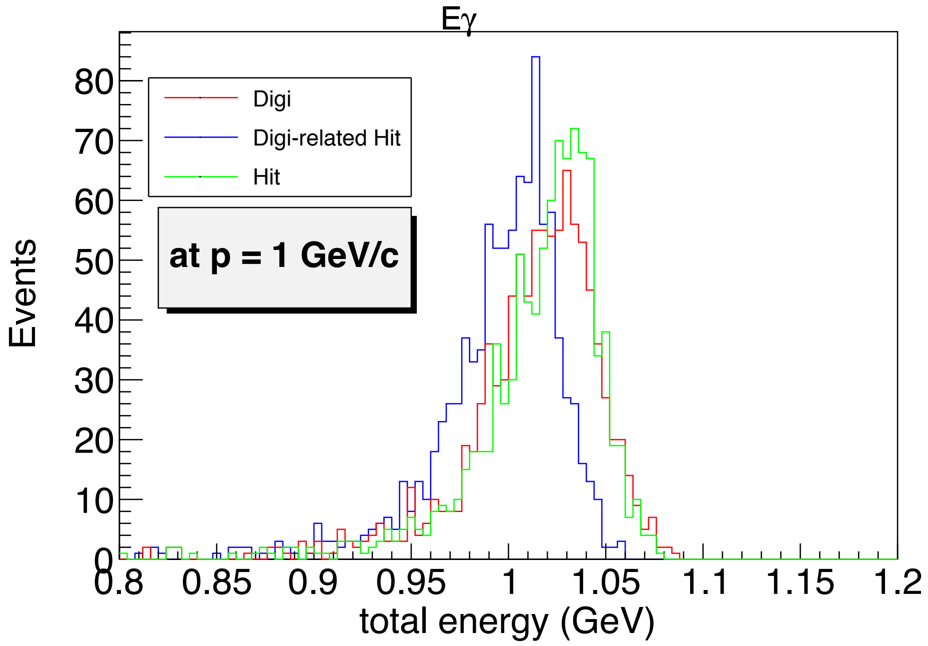
The FPGAs perform the following tasks:

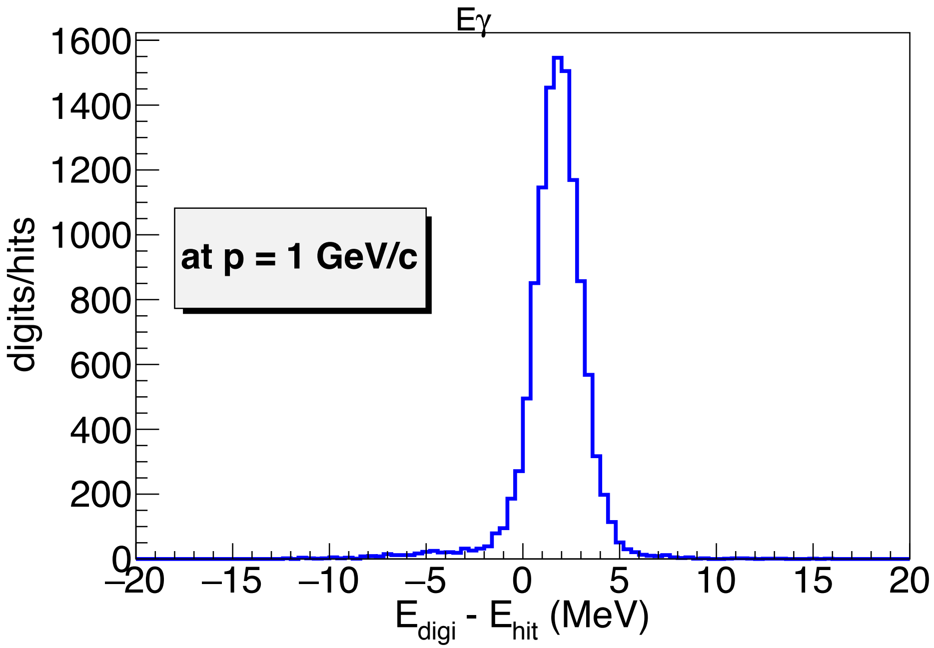
- time adjustment and distribution of the global clock signal;
- noise calibration;
- common mode noise suppression;
- pedestal subtraction;
- autonomous hit detection;
- conversion of ADC data and linearization of the full data range;
- transporting the hit information together with the time stamp to the data multiplexer;
- slow control.

From EMC TDR 2008

EMC Simulation: electronic response

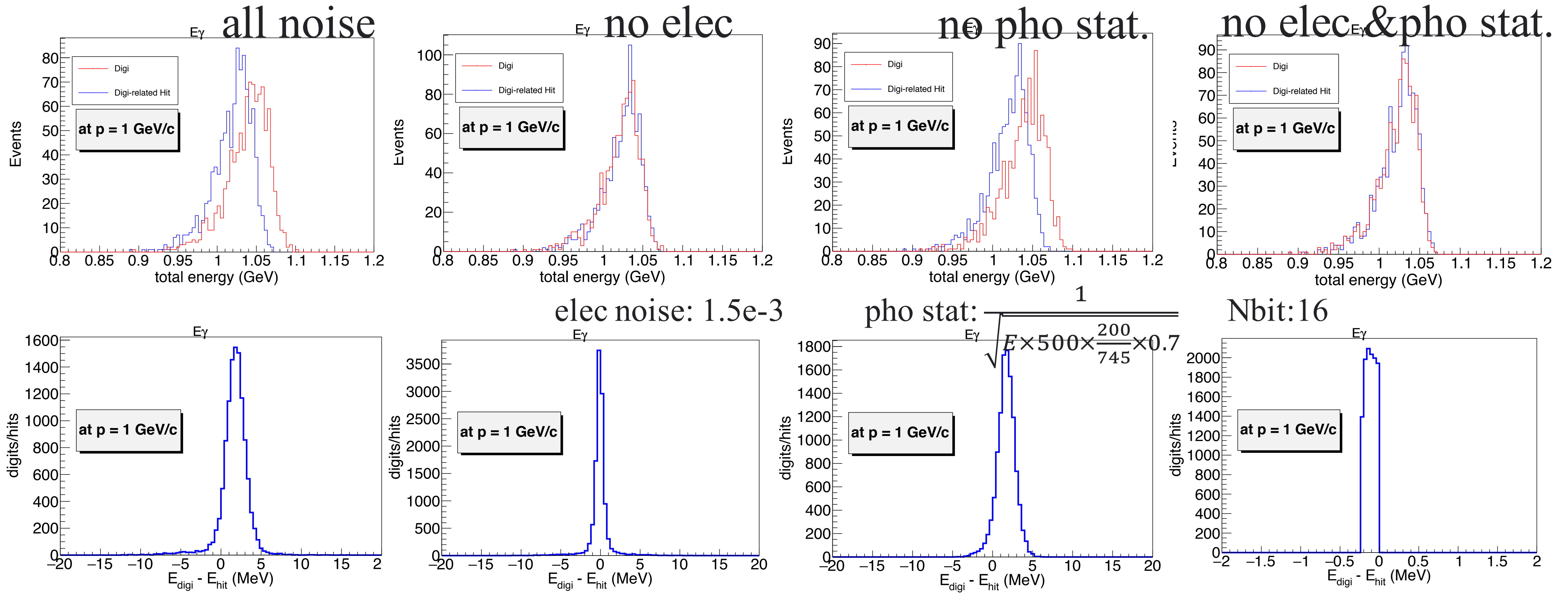
- Digitization: PndEmcDigi
  - Digitized energy and compared to Hits



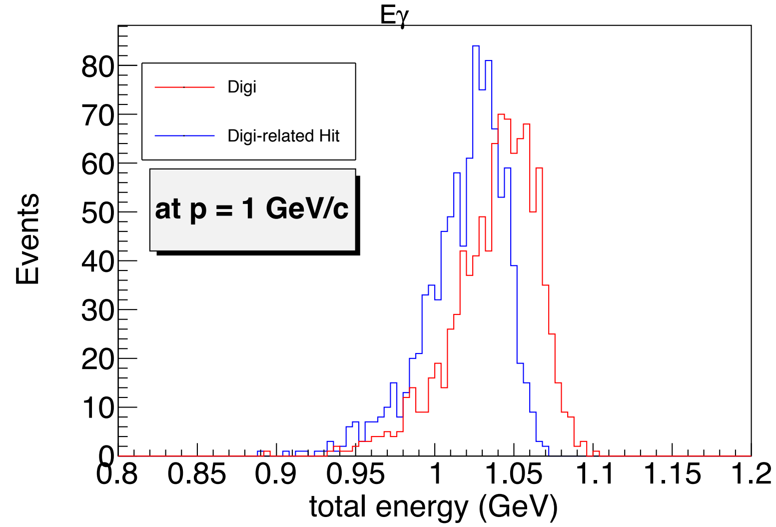


EMC Simulation: electronic response

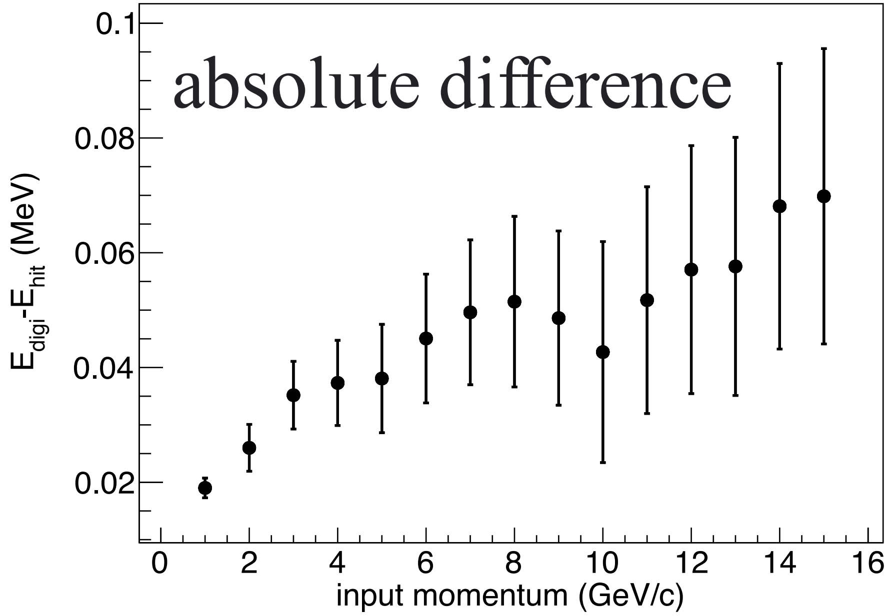
- Digitization: PndEmcDigi
  - E_{digi} Vs E_{hit} (top plots: event energy; bottom plots: crystal energy)

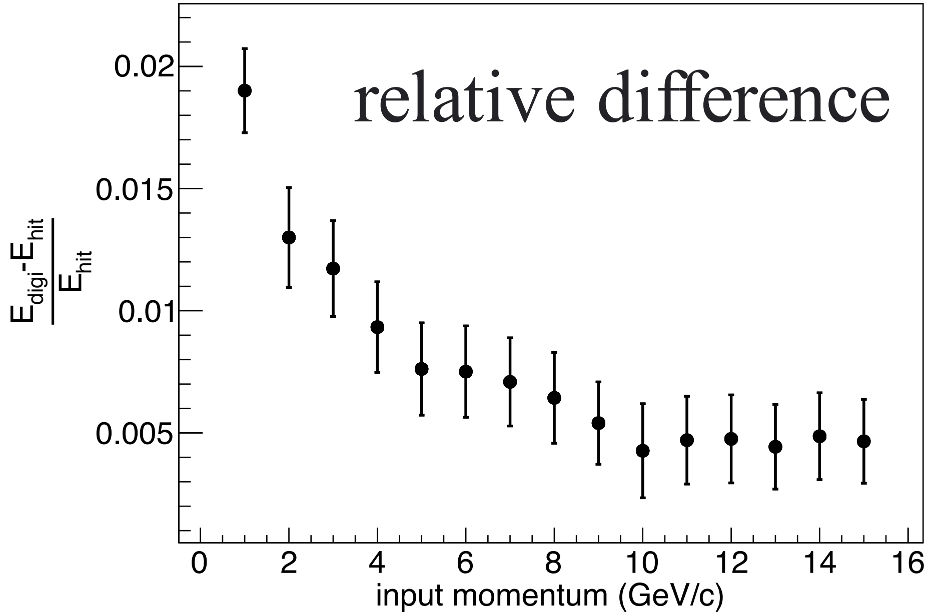


EMC Simulation: electronic response



- Digitization: PndEmcDigi
  - Event energy E_{digi} Vs E_{hit}



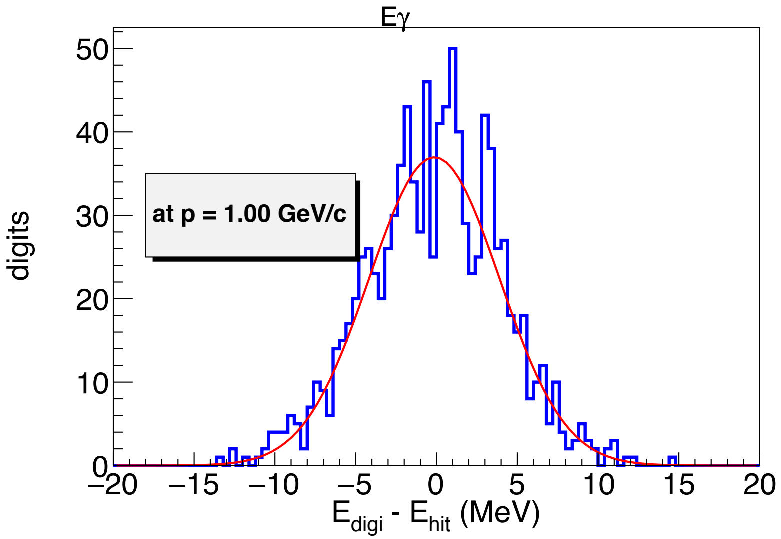


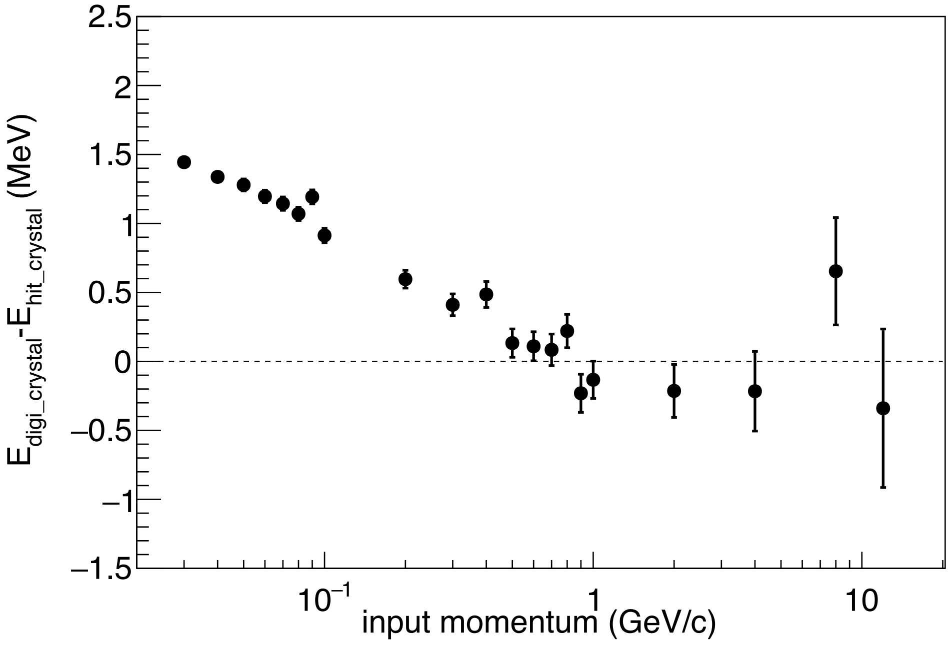
Relative difference get smaller at high energies

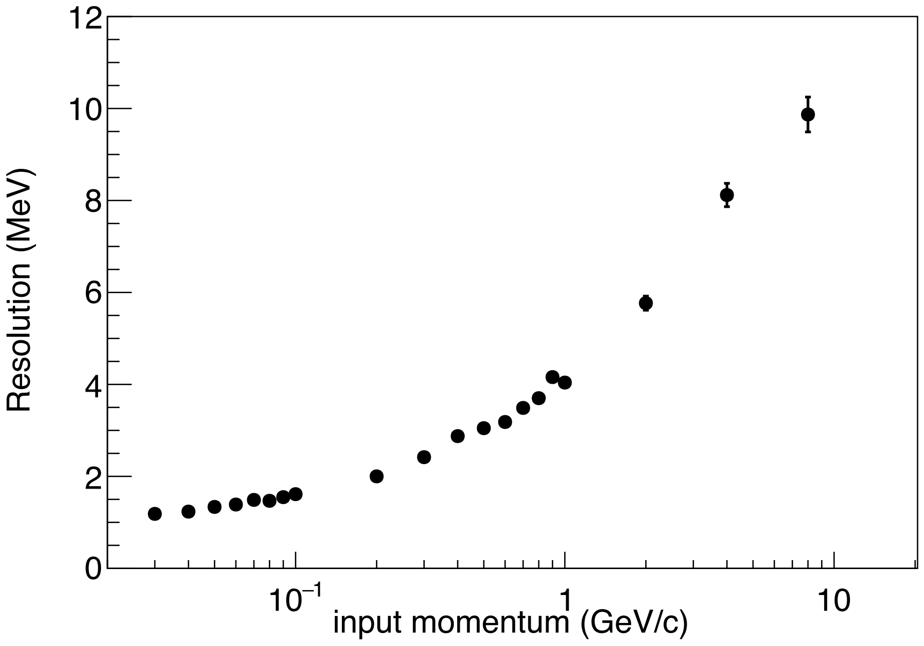
EMC Simulation: electronic response

➢ Digitization: PndEmcDigi

- Crystal energy E_{digi} Vs E_{hit}
  in the bar with maximum deposition







At higher input energy, smaller bias

Summary

Work has been done:

- Simulation has been checked from particle incidence to signal digitization
- Results in MCTrack, EmcPoint, EmcHit, EmcWave, EmcDigi seem reasonable.

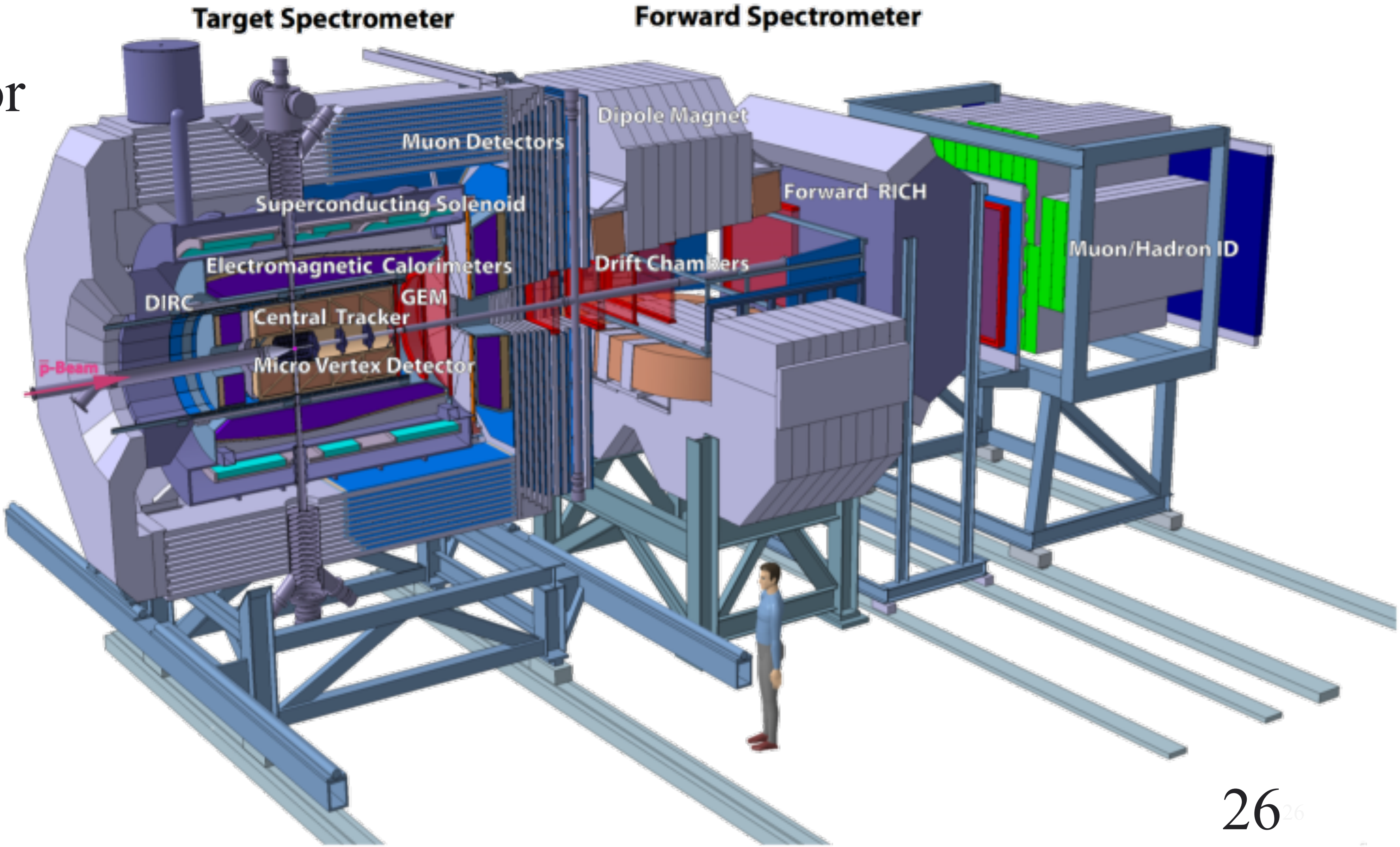
Work to do:

- more careful check: position, PID, efficiency, …
- contact with hardware exports for validation of the software: detector and electronics
- compare with prototype test or other experimental result

Thank you for your attention!

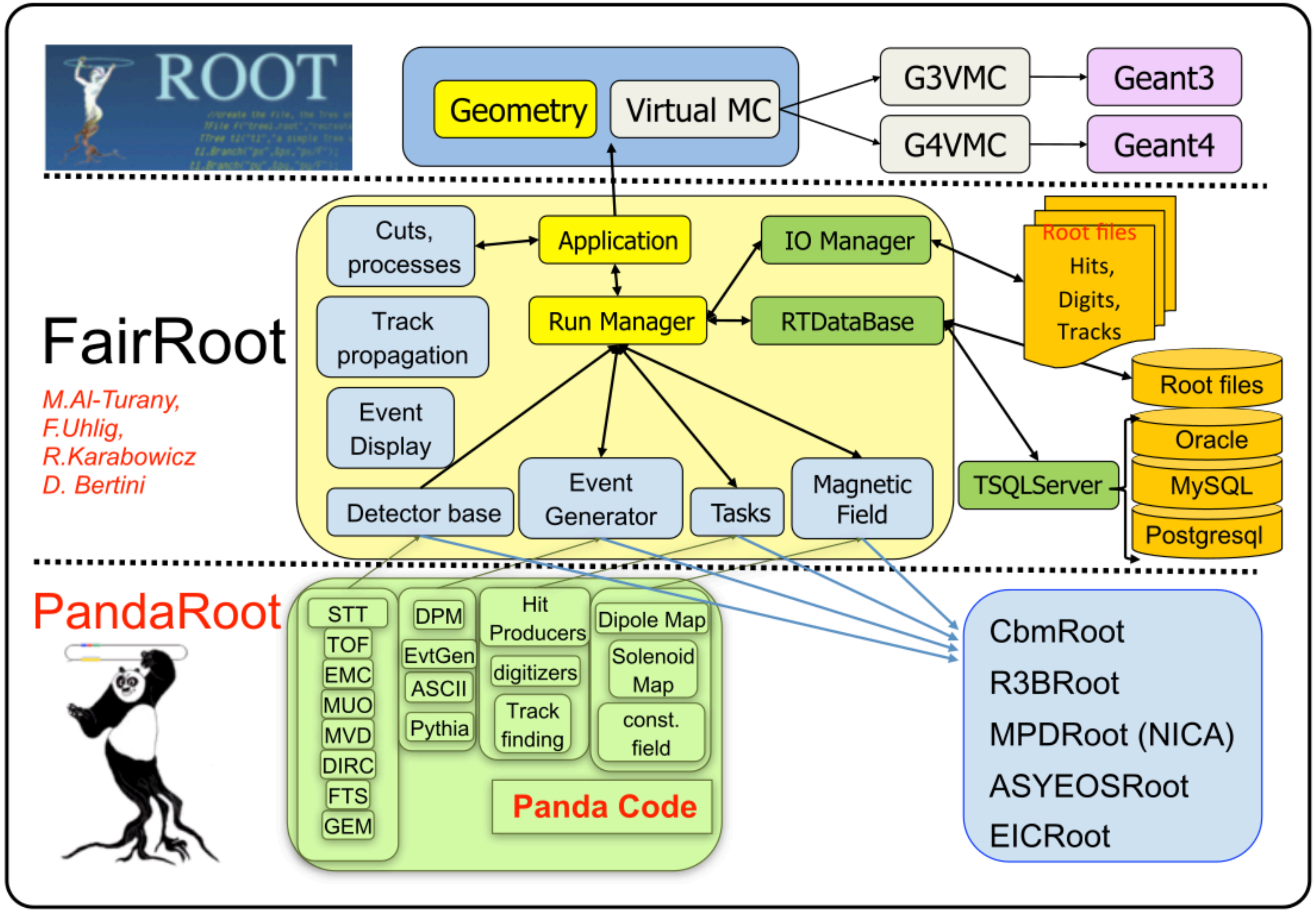
Introduction: Detector

- Detector



Introduction: Software

- Software



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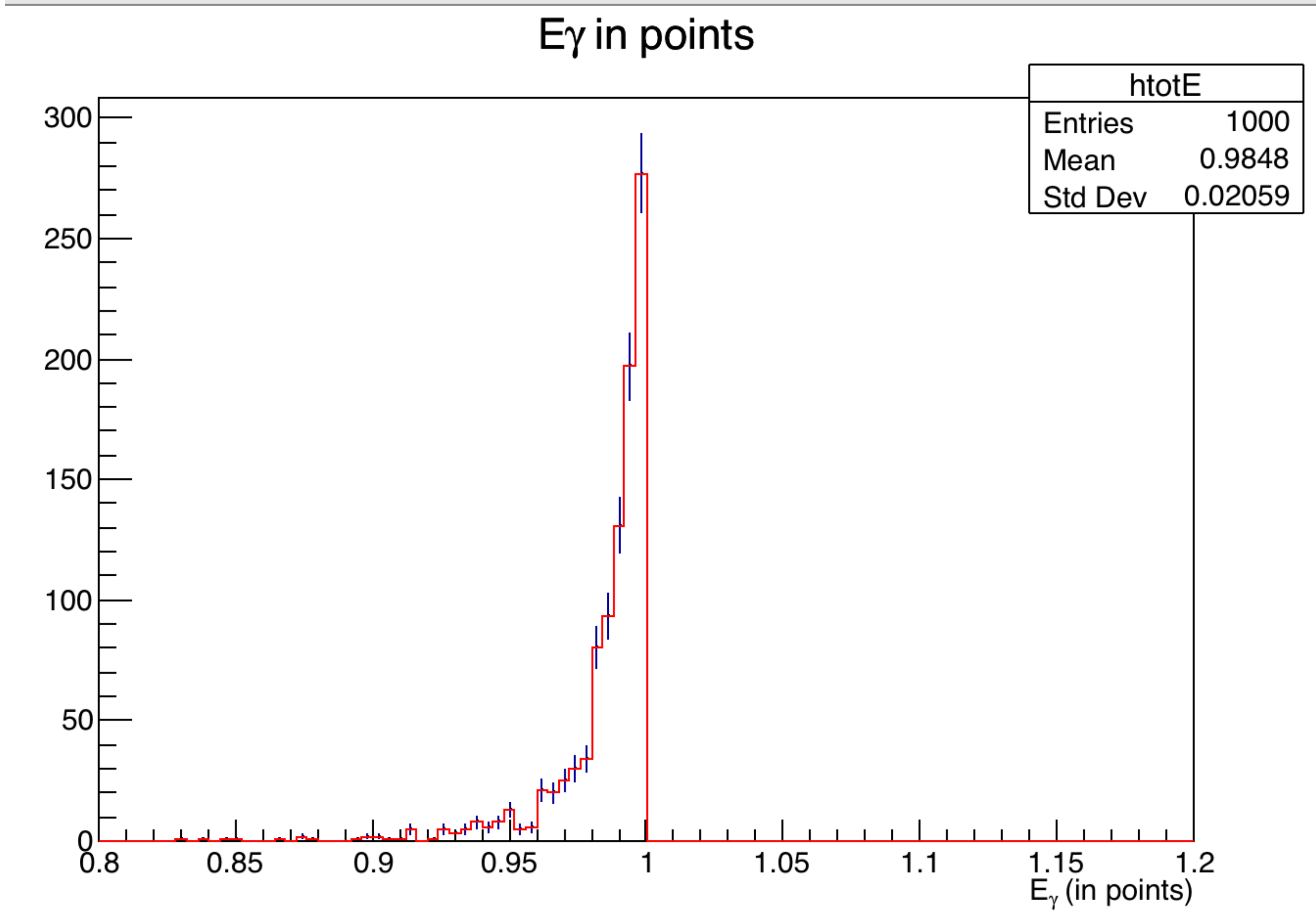
Simulation, example at 1 GeV/c

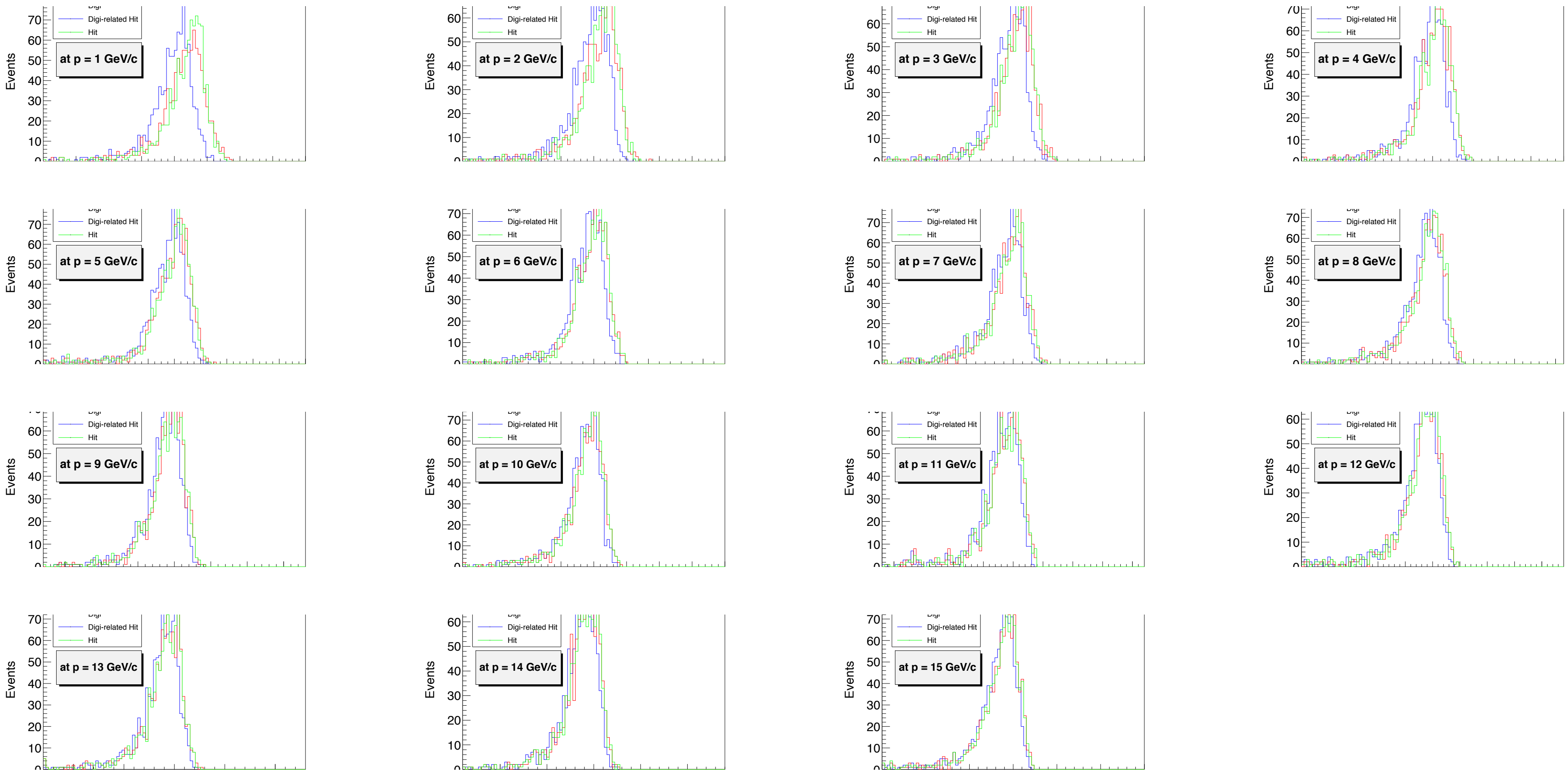
Total Energy in PndEmcPoints
Total Energy in PndEmcHit

If no nonuniformity, energy in points and hits are the same.



EMC Simulation: electronic response

- Digitization: PndEmcDigi
  - total energy E_{digi} Vs E_{Hit}, difference get smaller at high energys



EMC Simulation: electronic response

- Digitization: PndEmcDigi
  - crystal energy E_{digi} Vs E_{Hit}, differences are similar at different Eγ